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HUMAN FACTORS RESEARCH IN COMPLEX ELECTRONIC SYSTEMS, (U)
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RESEARCH STUDY 61-3

HUMAN FACTORS RESEARCH IN COMPLEX ELECTRONIC SYSTEMS

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Research Study 61-3

(6) HUMAN FACTORS RESEARCH IN COMPLEX ELECTRONIC SYSTEMS

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Research Studies are special reports to military management. They are usually prepared to meet requests for research results bearing on specific management problems. A limited distribution is made--primarily to the operating agencies directly involved.

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BRIEF

HUMAN FACTORS RESEARCH IN COMPLEX ELECTRONIC SYSTEMS

REQUIREMENT:

Since the overall effectiveness of electronic man-machine systems depends ultimately on the human components, the need for human factors information is paramount. The objective of the research effort reported in the present study is to bring about the best utilization of personnel in these systems. This objective can be accomplished through improved identification of appropriate personnel and their assignment to critical positions, and through the development of optimum work methods and SOP's for the operations they must perform.

PROCEDURE:

An experimental Electronics Selection Battery of tests was designed to provide better differentiation and identification of personnel who will succeed in electronics and electrical MOS of high versus low levels of complexity. Emphasis is being placed on job performance as the primary standard for evaluating the tests. Data have been collected and analysis is under way.

A comprehensive survey of human factors problems was undertaken in approximately 25 weapons, communications, and related systems in CONUS and USAREUR. Battlefield Air Defense Systems (Missile Monitor) were selected as meriting immediate intensive study. The pressing human factors problems in the Missile Monitor are associated with the performance of such critical functions as detection and monitoring of airborne targets on radar scopes, target tracking and radar data processing, assignment of weapons against airborne targets, and communication and control.

POTENTIAL MILITARY PAYOFF:

1. Improved work methods and SOP's.
2. Improved identification and assignment of personnel.
3. Improved general level of on-job performance.
4. Objective performance measures for the evaluation of system and subsystem effectiveness.

HUMAN FACTORS RESEARCH IN COMPLEX ELECTRONIC SYSTEMS

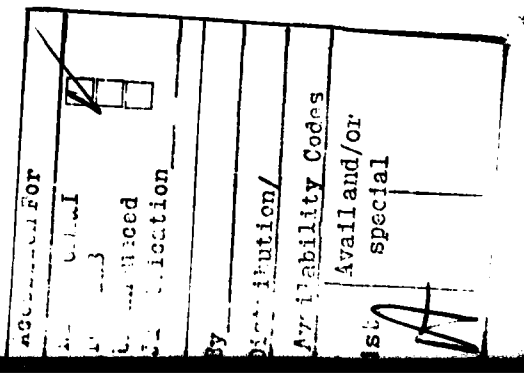
BACKGROUND

New concepts of warfare have brought about the introduction of unique and complex weapons systems into the Army. Various staff and field organizations are charged with responsibilities for maximizing the operational effectiveness of these systems. Since the overall effectiveness of these new electronic man-machine systems depends ultimately on the human components, the need for human factors information is paramount. In response to this need, the Electronics Task was approved by the Chief, Research and Development and assigned to the Human Factors Research Branch of TAG, R and D Command. Thus far, HFRB has conducted exploratory studies to identify and delineate those human factors problem areas which have the greatest impact on the Army's mission and which promise a good return for research effort in the form of useful and generalizable results, quickly and economically obtained.

The objective of the Electronics Research Task is to bring about the best selection, classification, and utilization of personnel in these systems. This can be accomplished through improved selection and assignment procedures and through the development of optimum work methods and SOP's for the operations that must be performed.

SELECTION AND CLASSIFICATION RESEARCH EFFORT

Research psychologists of the Support Systems Research Laboratory in HFRB assigned to the Electronics Task first tackled the problem of increasing the quantity and quality of personnel in electronics maintenance MOS. An experimental Electronics Selection Battery of tests was designed to provide better differentiation and identification of personnel who will succeed in electronics and electrical MOS of high versus low levels of complexity. The experimental Electronics Selection Battery was administered to approximately 5,000 personnel in Signal, Ordnance, and Combat Arms electronics and electrical courses and MOS of high, intermediate, and low levels of complexity. Emphasis is being placed on job performance (ratings) as the primary standard for evaluating the tests. These data are currently in analysis. When the effectiveness of these experimental tests is known, it will be compared with the effectiveness of tests currently employed in the Army Classification Battery. On the basis of these comparisons, revisions will be considered for the Army Classification Battery.



INITIATING UTILIZATION RESEARCH

The other major aspect of the Electronics Task research effort is improved utilization of human abilities in complex electronic man-machine systems through the development of effective individual and group work methods and techniques. From the onset of research effort, it was recognized by both military users and research specialists that only through consideration of both selection and utilization problems would major improvements in systems effectiveness be possible. Training problems and problems dealing with the design or redesign of equipment from a human engineering point of view were explicitly excluded from consideration, however, as falling outside of the mission of the Human Factors Research Branch.

A comprehensive survey of human factors problems was undertaken in approximately 25 weapons, communications, and related systems in CONUS and USAREUR to initiate utilization phases of the Task. The survey took place while selection research data were being collected. Visits were made to operational units in the field, to training centers, schools, USCONARC boards, and proving grounds. HFRB scientists participated in exercises, observed systems in operation, and interviewed personnel knowledgeable in the various systems, associated equipment, and organizations. The installations and organizations visited for data collection and survey purposes were:

CONUS

USARADCOM, Ent AFB, Colorado

U. S. Army Air Defense Center, Fort Bliss, Texas

White Sands Missile Range, Texas

Washington Air Defense Sector, Fort Lee, Virginia

Systems Development Corporation, Lodi, New Jersey

35th Brigade (AD), Missile Master, Fort George G. Meade, Md.

Office of the Chief Signal Officer, Washington, D. C.

U. S. Army Signal Air Defense Engineering Agency, Fort Meade, Md.

The Signal School, Fort Monmouth, N. J.

The U. S. Army Artillery and Missile Center, Fort Sill, Okla.

Redstone Arsenal, Huntsville, Ala.

2d U. S. Medium Missile Command, Fort Carson, Colo.

Human Engineering Laboratory, Aberdeen Proving Ground, Md.

584th Ordnance Detachment, Fort George G. Meade, Md.

Command Center, ACAN, Pentagon

ACAN Transmitter Station, Woodbridge, Va.

ACAN Receiver Station, LaPlata, Md.

USAREUR

75 combat ready Ordnance, Signal and Combat Arms units.

The systems surveyed were as follows:

Surface to Air Missiles

Fire Distribution

Surface to Surface Missiles

Radar

Meteorological

Surveying

Automatic Data Processing

Communications

Aerial Surveillance

Many factors were considered in arriving at a decision as to the system(s) to which the research resources of the Electronics Task would be applied. These factors may be categorized into the following three classes:

Expression of Requirements

System Considerations

Research Considerations

The expression of requirements included the following:

1. Statements of human factors problems and research needs.
2. Requests for assistance.

The system considerations were:

1. Importance of the system to the Army mission.
2. Newness and relative inexperience with the system.
3. Complexity of the system and the operations that must be performed.
4. Stage of evolution, modification, replacement, and automation of the system.
5. Emergency nature and response time required of the system.

The research considerations were as follows:

1. Amount of on-going research effort in the area of utilization of personnel.
2. Degree to which the problems encountered were isolated and discrete and not amenable to logical integration into a larger, integrated, and more economical program.
3. Degree to which the problems fell within the HFRB mission of selection, classification, assignment, and utilization rather than in the areas of human engineering and training research.
4. Degree to which the problems were amenable to research.
5. Miscellaneous considerations such as availability of systems and equipment, the possibilities of simulation, speed and economy of research, and potential return for research effort.

On the basis of all of the above-mentioned factors, several systems were viewed as meriting study from a selection and utilization research point of view --Battlefield Air Defense (Missile Monitor, Hawk, Nike Hercules), Communications, and Automatic Data Processing. On a relative priority basis, however, Battlefield Air Defense Systems--with emphasis on the Missile Monitor Fire Distribution System--were selected as warranting immediate intensive study.

BATTLEFIELD AIR DEFENSE SYSTEMS

In an era in which high speed and destructive power are bywords of military operations, defense of troops and equipment from air attack is a prime concern. For this purpose, the Army has developed integrated systems of radar air surveillance, fire distribution and control, and surface-to-air weapons. One such surveillance and fire distribution system is the Missile Monitor; the weapons systems are the Hawk and Nike Hercules. This entire air defense system is designed for mobile employment against low and high flying aircraft in the battlefield situation.

THE MISSILE MONITOR

In the Missile Monitor, two vans are critical to successful operation--the Radar Data Processing Van and the Weapons Control Van. A number of important operations and functions must be performed effectively by humans in these vans. In the Radar Data Processing Van, personnel are required to detect and monitor targets on radar scopes, track targets, determine their height, identity, and raid size, input this information into computers, and retrieve information from the computers. In the

Weapons Control Van, Weapons Control Officers are required to integrate all of this target information with weapons and other information coming from various sources, make decisions on the priorities, distribution, and coordination of fire of a number of batteries at a number of targets, communicate these decisions, see that they are implemented, and maintain control over their sectors of responsibility so that they will be constantly aware of the status of the situation. All of these operations and functions are performed through the use of a large array of displays (scopes, lights, status boards, dials), controls (tracking sticks, buttons, knobs, switches), and symbols (See Figure 1). Further, they may have to be performed under a wide variety of conditions ranging from those which induce boredom and apathy to those which strain the limits of human capabilities and endurance. These operations, functions, and conditions are also found at battalion and battery levels, except for differences in size of area, number and type of targets, and number and type of weapons.

BFADS are highly advanced and sophisticated in design. Although the Army is constantly engaged in improving its equipment and systems, replacement by radically different systems in the near future is not anticipated.

Figure 1. Example of operator console.

THE NEED FOR HUMAN FACTORS RESEARCH

The need for human factors research in BFADS arises out of the very newness of these systems and the demands made on human beings as essential components of the systems. The kind and number of operations that must be performed, the speed and precision with which they must be performed, the conditions under which they must be performed, and the inextricable interdependencies among men and equipment leave little room for human inefficiency, error, or failure, giving rise to the following broad human factors research question: What can be done to improve the utilization and performance of human beings in critical positions of BFADS so that the operational effectiveness of these systems is at a maximum?

To answer this question, a four-pronged research attack has been planned:

1. Performance measures must be developed for systems, subsystems, and individual human beings.
2. Human performance characteristics must be described and specified.
3. Optimum work methods and SOP's must be devised.
4. Identification of appropriate personnel and their assignment to critical positions must be improved.

It is hoped that this formulation will provide a comprehensive and integrated human factors research approach to such critical BFADS functions as detection and monitoring of airborne targets on radar scopes, target tracking and radar data processing, assignment of weapons against airborne targets, and communication and control. Although this research involves systems that are operational or in the user-test phase of development, attention is being focussed on areas and problems of human performance that generalize to future systems.

RESEARCH APPROACHES

PERFORMANCE MEASURES

Performance measures are needed at three levels: at the total system level, at the subsystem level, and the level within a system or subsystem where individuals operate in critical positions. By taking measures at these three levels simultaneously, the relationships among them can be more easily ascertained. It may be possible to predict the effects of changes in performance at one level on performance at other levels. Such information is necessary to avoid a situation wherein performance is improved at the subsystem or individual level but only at the expense of total system performance.

To the maximum extent possible, the performance measures will be objective. They may be obtained from records that are routinely maintained or from forms devised specifically for these studies. In some cases, judgments by knowledgeable operational personnel may be used. The kinds of measures contemplated vary in their specificity and inclusiveness by design--Examples are as follows:

1. Distance at which aircraft are detected and identified
2. Speed of tracking and updating radar blips.
3. Speed of complete processing of radar blips.
4. Accuracy of tracking and updating radar blips.
5. Accuracy of complete processing of radar blips.
6. Speed of assignment of targets to missile batteries.
7. Appropriateness of assignment of targets to missile batteries.
8. Time for battery to lock-on target after receipt of assignment.
9. Time from detection of target at Radar Processing Van to lock-on by missile battery.

Relevant and objective performance measures are a basic requirement for all further research. The efforts in this area of research are expected to yield *measures of performance* to reflect the effects of variations in any conditions or variables (target, environmental, psychological), and work methods and SOP's. Examination of such effects will make it possible to identify those factors which make a significant contribution to the overall success or failure of the system. Such measures will be of use to commanders in assessing the capabilities of their system, subsystems, and individuals in locating sources of inefficiency.

SPECIFICATION OF HUMAN PERFORMANCE CHARACTERISTICS

Prior to the development of optimum work methods and SOP's, and means for improved identification and assignment of personnel to critical positions, it will be necessary to ascertain the effects of various conditions on the performance of critical functions. Through a series of such studies, much can be learned about degradation and enhancement of performance, human limits and reliability, and the factors which underlie the performance of critical functions. Taking, as a point of departure, the BFADS hardware as given, at least three major classes of conditions or variables merit attention.

1. Targets may vary in such respects as rate of appearance, locations, number, density, size, speed, behavior, and enemy countermeasures employed.

2. Environmental variables and conditions are concerned with variations in the physical environment such as terrain, weather, noise, vibration, and temperature; attention will also be focussed on the social environment, including such aspects as functions allocated, degree of isolation, degree of independence of work, extent of group work, and the nature of the interactions required among individuals.

3. Psychological variables and conditions include such psycnological dimensions as aptitudes, skills, and personality/motivational variables as well as such phenomena as boredom, stress, fatigue, and exhaustion.

Studies will be conducted in which the above conditions will be systematically varied while the performance of the critical functions and subsystem and system output will be observed and recorded in terms of the performance measures discussed earlier. Figure 2 illustrates the kind of descriptions and specifications of performance obtained in one tracking study conducted by the Electronics Task in a situation where work methods and SOP's may not have been optimal. The figure shows the relationship between the number of targets tracked with perfect accuracy and the number of targets assigned to be tracked. Each plotted point represents a mean of 19 trackers, some of whom performed close to the maximum. In general, while the absolute number of targets tracked with

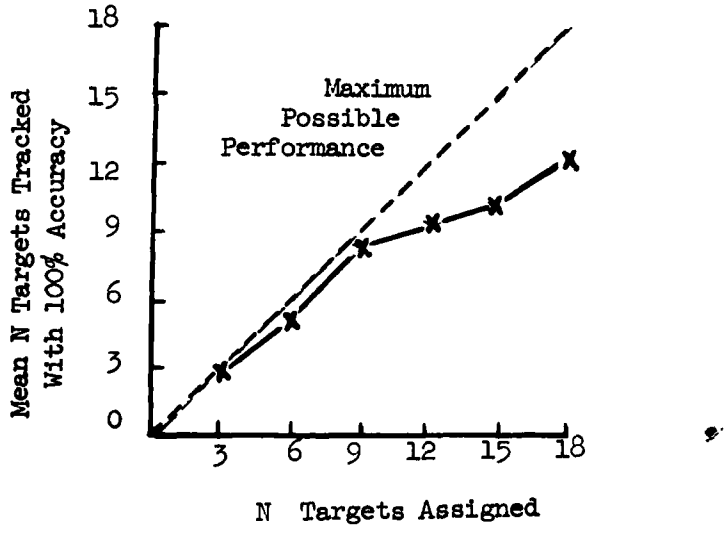


Figure 2. Tracking performance as a function of number of targets assigned.

perfect accuracy increased through all load levels of the experiment, it is evident that there was considerable room for improvement.

Such studies furnish information on individual, subsystem, and system performance under anticipated ranges and combinations of conditions. Descriptions and specifications of the performance of critical functions should then be possible. Those conditions which in fact have a significant effect on performance will be identified. Estimates of the capabilities and limits of individuals, subsystems, and the total system will be possible.

These studies which are preliminary, for the most part, will also make possible the generation of hypotheses concerning optimum allocation of functions or division of labor, work methods, and SOP's. Further, information on the nature, number, and combinations of aptitudes, skills, and other psychological variables which underlie the performance of critical functions will be ascertained. Finally, the information resulting from these studies will be used as a basis for making recommendations which also may be applicable to future systems.

OPTIMUM WORK METHODS AND SOP's

While work methods and SOP's may receive attention from the earliest conception of a new system through its design and development, they usually undergo modification as military experience with the system develops. By and large, however, there has been little opportunity to determine experimentally and precisely the optimum work methods and SOP's for a given system using operational equipment and personnel. The research proposed here would determine, through controlled experimentation, such factors as the optimum allocation of functions to personnel or division of labor, work methods, and SOP's. This effort would be oriented toward improvement of the system through recommendations concerning the utilization of personnel rather than through modification of current equipment.

Some examples of the kinds of studies that will be conducted and questions that will be pursued are as follows:

1. Under what conditions, if any, should target detection and monitoring functions and target tracking and radar data processing functions be performed by single individuals and under what conditions should these functions be shredded out and distributed to two or more individuals?

2. Under what conditions should Detector-Trackers be responsible for targets in the complete 360° radar arc surrounding them, for targets in some portion of that arc, for targets at varying altitudes, for targets at varying ranges, for targets at various combinations of arcs, altitudes and ranges?

3. What are the optimum combinations of speed and accuracy of target tracking and radar data processing for maximizing system output in terms of number of targets the entire system will handle and lock-on time by the batteries?

4. What decision-making principles, techniques, and aids would be of greatest use to the Weapons Monitor in his job of monitoring or assigning weapon-target engagements from the point of view of speed and appropriateness of target coverage? What are the most critical items of information that he must use and in what order? What are the best ways for him to resolve conflicting information from different sources--Missile Monitor radar versus Hawk radar, for example?

5. In the area of communication and control by the Weapons Monitor and similar positions, there are questions concerning optimum work methods and techniques for maintaining control over the implementation of missions. These questions are particularly important when there are a large number and variety of enemy aircraft and when the system is being taxed near or to its limit. Here the research will be concerned with improving communication procedures, speed, accuracy, and methods for maintaining a clear picture of the status of the situation for control purposes.

The research paradigm for the studies and questions just poised is a straightforward one. Alternative work methods and SOP's will be tried under carefully controlled conditions. Their relative effectiveness will be compared in terms of system output and performance measures discussed above. On the basis of the results, recommendations will be made for operational adoption of those work methods and SOP's which yield the greatest system output.

IDENTIFICATION AND ASSIGNMENT OF PERSONNEL TO CRITICAL POSITIONS

Two major research approaches can be employed to improve the assignment of individuals to critical positions within these systems. The first is to develop classification instruments designed to identify appropriate personnel for the various electronics training programs and jobs. The second is to develop procedures for placing individuals, after classifications and training, into particular positions within a system, taking into account a variety of measures including individual and group skills and abilities. The research involving the Electronics Selection Battery addresses itself to the former problem.

The objective of the research falling in the area of assignment of personnel is to develop and validate instruments and procedures for improved identification and assignment of individuals and groups to critical positions in mobile Battlefield Air Defense Systems. In the process of ascertaining the effects of various conditions on the performance of critical functions and developing optimum work methods and SOP's, a great deal will be learned about the underlying psychological variables involved in the performance of individuals and groups. Much of the research discussed above will yield information on the nature, number, level, combination, and organization of aptitudes and abilities required of individuals and teams working in mobile Battlefield Air Defense Systems. Moreover, in order to conduct some of the research discussed earlier, it will be necessary to have measures of a number of relevant psychological variables. By relating these measures (as well as others designed specifically for assignment purposes, such as performance measures and information obtained from training records) to the system measures discussed above, it will be possible to prepare instruments for use within the system for assigning personnel to the critical positions in the systems. While it may be difficult to obtain measures differential for the several positions within the Battlefield Air Defense Systems, much may still be achieved by insuring that the best men are placed in the most crucial positions. It should be added that the research efforts in each of the other areas will tie in to the assignment problem by establishing principles basic to the operation of the system, and permitting the use of this information to determine which systems' functions are most crucial and most in need of enhancement through assignment of top personnel.

The end products of the research in this area will be instruments and procedures for identifying and assigning those personnel with the best potential for on-job success in the critical positions in mobile Battlefield Air Defense Systems.

RESEARCH TECHNIQUES

SIMULATION

In some instances research concepts may be tested by analytical treatment of logical models, with recourse to computer simulation if necessary. This procedure will serve as a screening process for reducing the amount of research studies to be conducted and the time to conduct them, and will permit focussing and emphasis on the most important problems. Further, in order to minimize the requirements for and interference with operational systems, laboratory-type simulation equipment and methods will be used. On occasion, an older system (Missile Master) may serve as a simulator for a more advanced one (Missile Monitor), while the former one is being studied in its own right.

OPERATIONAL SYSTEMS

It will also be necessary to do a substantial portion of the research using operational systems and personnel in the field or at training centers. This is particularly important where it is not possible to simulate the systems with sufficient fidelity and when final testing and validation of research hypotheses must be conducted.

SUMMARY

The research program presented above is an attempt at a comprehensive and integrated effort toward solving pressing human factors problems in Battlefield Air Defense Systems. The problems are associated with the performance of such critical functions as detecting and monitoring airborne targets on radar scopes, target tracking and radar data processing, assigning weapons against airborne targets, and communication and control. Solutions and alleviation of the problems will take the form of improved work methods and SOP's, and improved identification and assignment of personnel with respect to critical positions.

Several projects were initiated dealing with the first two critical functions mentioned--detection and monitoring of airborne targets on radar scopes and target tracking and radar data processing. These functions contribute early, if not the first, input into an air defense fire distribution system and provide important data on the basis of which decisions must be made concerning the priorities, distribution, and coordination of fire of a number of batteries at a number of targets. Obviously, if the former functions are not performed effectively, the purpose and mission of Battlefield Air Defense Systems will be defeated, regardless of how well the latter functions are performed. Research on the latter functions will be initiated as resources permit.